Questions from the textbook: From Chapter 2 page 78, 79 & 80

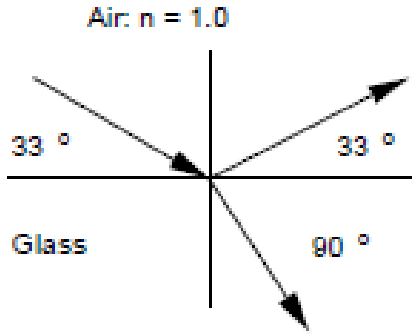
Example 2-3 page 45:

A step-index fiber has a normalized frequency V = 26.6 at a 1300-nm wavelength. If the core radius is 25 μ m, let us find the numerical aperture.

$$V = \frac{2\pi}{\lambda} a\,N.A. \quad \Rightarrow \quad N.A = \frac{\lambda \times V}{a \times 2 \times \pi}$$

$$N.A = \frac{1300 \times 10^{-9}\,m \times 26.6}{25 \times 10^{-6}\,m \times 2 \times 3.14} = 0.2203$$

2.6 Light traveling in air strikes a glass plate at an angle $\Theta_1 = 33^\circ$, where Θ_1 is measured between the incoming ray and the glass surface. Upon striking the glass, part of the beam is reflected and part is refracted. If the refracted and the reflected beams make an angle of 90° with each other, what is the refractive index of the glass? What is the critical angle for this glass?



a) Using Snell's law

$n_1 \sin(90-33) = n_2 \sin(33)$

$0.84 = n_2 (0.55)$

$n_2 = 0.84 / 0.55$

$= 1.539 = 1.54^\circ$

b) The critical angle can be found using

$\phi_c = \sin^{-1}(1/1.54)$

$= \sin^{-1}(0.649) = 40.5^\circ$

2.9 Calculate the numerical aperture of a step-index fiber having $n_1 = 1.48$ and $n_2 = 1.46$. What is the maximum entrance angle $\Theta_{0,max}$ for this fiber if the outer medium is air with n =1?

N.A. $= [n_1^2 - n_2^2]^{0.5} = [(1.48)^2 - (1.46)^2]^{0.5} \approx$ **0.24**

$\alpha_{max} = \sin^{-1}[N.A./n_0] = \sin^{-1}[0.24/1] \approx$ **14°**

2.20 determine the normalized frequency at 0.82 μ m for a step-index fiber having a 25-μ m core radius, n1 = 1.48, and n2= 1.46. How many modes propagate in this fiber at 0.82 μ m? How many modes propagate at a wavelength of 1.3 μ m? ~~What percentage of the optical power flows in the cladding in each case?~~

$$V = \frac{2\pi}{\lambda} a\,N.A.$$

N.A. $= [n_1^2 - n_2^2]^{0.5} = [(1.48)^2 - (1.46)^2]^{0.5} \approx$ **0.24**

$$V = \frac{2 \times 3.14 \times 25 \times 10^{-6}\,m \times 0.24}{0.82 \times 10^{-6}\,m} = \mathbf{46.45}$$

$M = V^2 / 2 =$ **1081 modes at 0.82 μ m**

M at 1.3 μ m

$$V = \frac{2 \times 3.14 \times 25 \times 10^{-6}\,m \times 0.24}{1.3 \times 10^{-6}\,m} = 29.29$$

$M = V^2 / 2 =$ **430 modes at 1.3 μ m**

2.29 Calculate the number of modes at 820 ηm and 1.3 μ m in a graded-index fiber having a parabolic-index profile (α=2), a 25- μ m core radius, n_1 = 1.48, and n_2= 1.46. How does this compare to a step-index fiber?

From the above question

At .82 μ m V= 46.45

At 1.3 μ m V= 29.29

Wavelength	V-number	Step-index Fiber M= $V^2/2$	Graded-index fiber M= $V^2/4$
0.82 μ m	46.45	1081	541
1.3 μ m	29.29	430	215

2.21 Find the core radius necessary for single-mode operation at 820nm of a step-index fiber with n_1= 1.480 and n_2= 1.478. What is the numerical aperture and maximum acceptance angle of this fiber?

N.A. = $[n_1^2 - n_2^2]^{0.5}$ = $[(1.48)^2 - (1.478)^2]^{0.5}$ = **0.0768**

$\alpha_{max} = \sin^{-1}[N.A./n_0] = \sin^{-1}[0.0768/1] \approx$ **4.4104°**

$V = \frac{2\pi}{\lambda}$ a N.A. ➡ $a = \frac{\lambda \times V}{2 \times \pi \times N.A.}$

For single mode fiber V < 2.405

$a = \frac{820 \times 10^{-9}_{m} \times 2.405}{2 \times 3.14 \times 0.0769}$ = **4 μ m**

2.22 A manufacturer wishes to make a silica-core, step-index fiber with V= 75 and a numerical aperture NA= 0.30 to be used at 820 nm. If n_1= 1.458, what should the core size and the cladding index be?

$V = \frac{2\pi}{\lambda}$ a N.A. ➡ $a = \frac{\lambda \times V}{2 \times \pi \times N.A.}$

$= \frac{75 \times 820 \times 10^{-9}_{m}}{2 \times 3.14 \times 0.3}$ = **32.64 *10 $^{-6}$ m =**

The core radius should be 32.64 μ m

N.A. = $[n_1^2 - n_2^2]^{0.5}$

0.3 = $[(1.458)^2 - (n_2)^2]^{0.5}$

$n_2 \approx 1.427$

The cladding index should be 1.427

2.30 Calculate the numerical apertures of:

a) a plastic step-index fiber having a core refractive index n1= 1.60 and a cladding index n2=1.49.

N.A. = $[n_1^2 - n_2^2]^{0.5}$ = $[(1.6)^2 - (1.49)^2]^{0.5}$ = 0.5830 ≈ **0.58**

b) a step-index fiber having a silica core (n1= 1.458) and a silicone cladding (n2=1.405).

N.A. = $[n_1^2 - n_2^2]^{0.5}$ = $[(1.458)^2 - (1.405)^2]^{0.5}$ = 0.3895 ≈ **0.39**